The Satellite Proving Ground: GOES and JPSS

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With contributions from, Lee Byerle, Galina Chirokova, John Knaff, Dan Lindsey, Steve Miller, Debra Molenar, Kate Musgrave, Andrea Schumacher, Chris Slocum, Dakota Smith, Stephanie Stevenson, Chris Velden, Joe Zajic

Outline

- Overview of the Satellite Proving Ground
- Proposed Satellite Proving Ground demonstration process
  - GOES, JPSS, TROPICS product examples
- New Infrastructure for Satellite Proving Ground
  - Cloud AWIPS for enhanced developer forecaster interactions
  - GeoIPS microwave data processing system
  - Hurricanes and Ocean Testbed (HOT)
- A look ahead to GeoXO

GOES-R Proving Ground/Risk Reduction

- GOES-8 Launched in April 1994, Data available fall of 1994
  - Much higher IR spatial resolution, separate sounder, faster sampling
  - NWS was not ready for GOES-8 (AWIPS delayed, forecasters not fully training)
- GOES-8 lessons learned: GOES-R PG/RR program started a decade before launch of GOES-16
  - Training directly with NWS National Centers and WFOs using proxy data
  - Satellite liaisons assigned to NCEP Centers and NWS Training Center
  - Algorithm Working Group - Pre-launch product development
  - GOES-R Risk Reduction – Directed grants program for new applications
  - Pre-launch real time demonstrations using proxy data (MeteoSat, etc)
  - Post-launch real time product demonstrations
- JPSS Proving Ground implemented for LEO satellites starting with S-NPP/NOAA20

Satellite Proving Ground Demonstrations

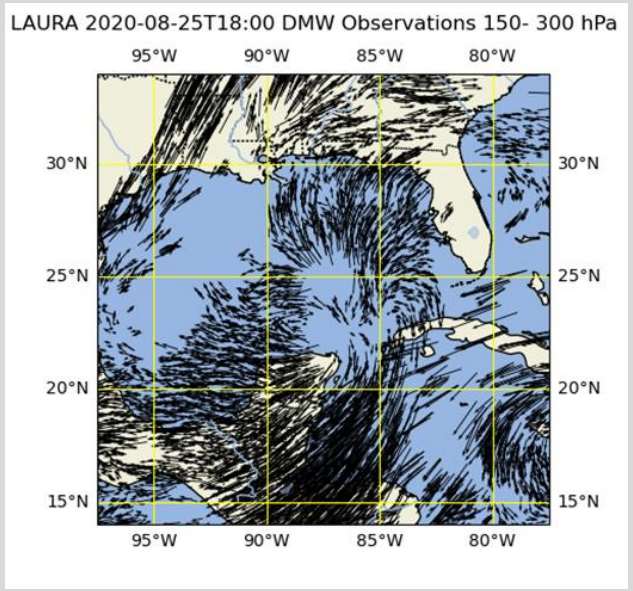
- Identify developmental satellite products with operational application
  - Situational Awareness or Quantitative
  - Must have path to operations
- Prepare training and validation
  - What is the “value added” compare with current capabilities?
- Prepare (short) demonstration plan
  - Research and operational POCs
  - Product generation and dissemination methods
    - External research location, servers at operational location?
    - Web-based, ATCF, operational AWIPS, cloud AWIPS?
  - Time frame of the demonstration
  - Evaluation method
    - Google form for forecaster feedback
    - Post-experiment verification of quantitative products
  - Post-season report and next steps
- Coordination with Joint Hurricane Testbed and HOT

Candidate GOES Satellite Proving Ground Products

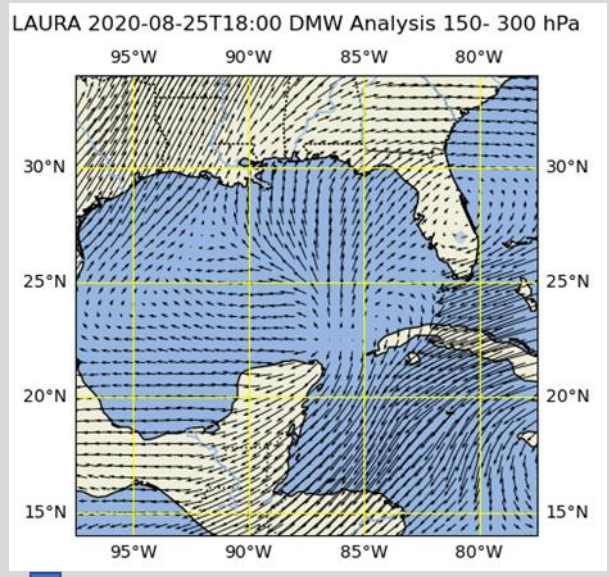
- Derived Motion Wind Rapid Intensification Diagnostics (DMW-RID)
- Experimental Rapid Intensification Indices (RII)
  - RII with GLM input (G-RII), Rapid Intensification Prediction Aid (RIPA)
- Updated ProxyVis Imagery from GOES and Himawari ABI
- Updated GeoColor Imagery from GOES
- Synthetic microwave imagery from ABI
- Combined GOES/NOAA-P3 TDR wind products

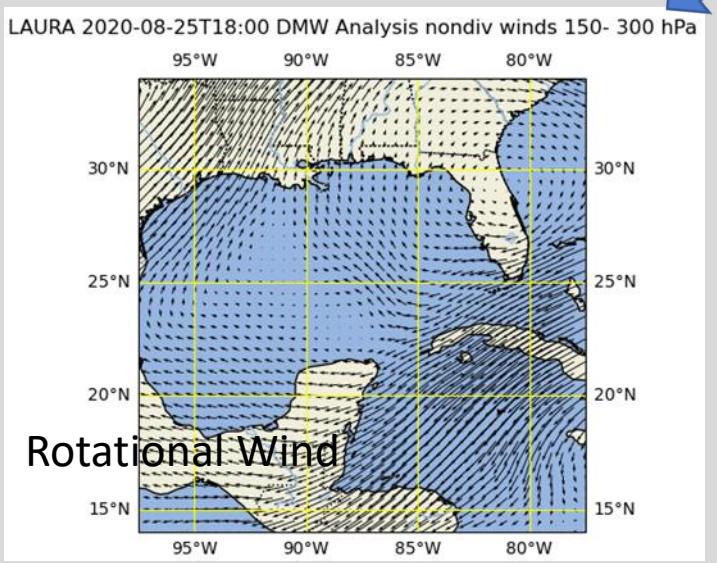
GOES DMW RI Diagnostics

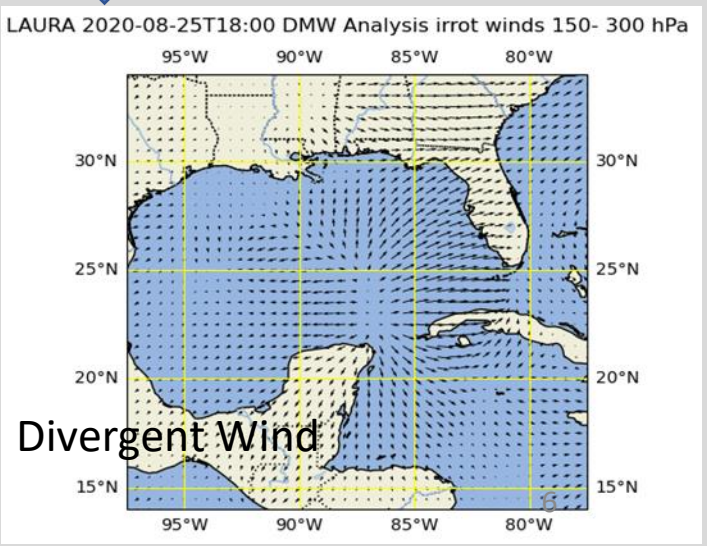
- Objective analysis of DMWs in outflow layer
- Decompose wind into irrotational and nondivergent parts
- Use divergent wind to diagnose environmental flow blocking
- POCs: M. DeMaria, A. Schumacher, D. Molenar, G. Chirokova



Objective analysis

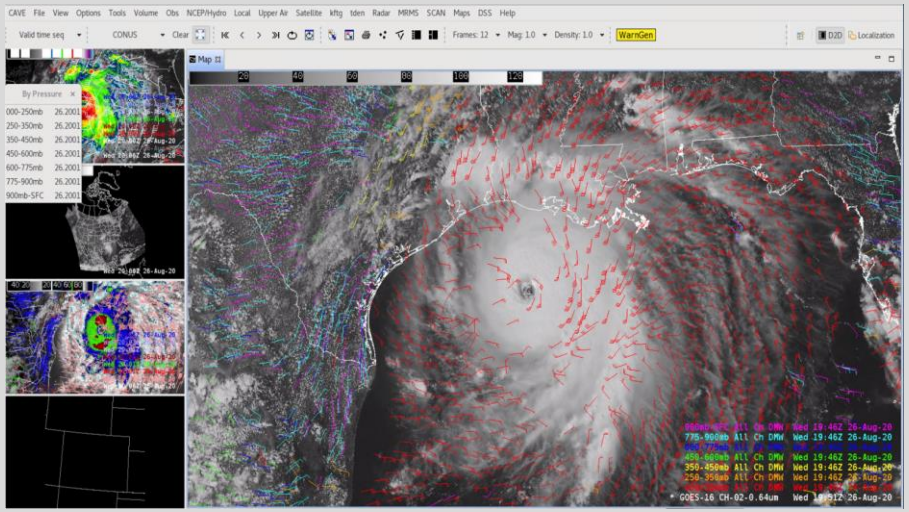






GOES DMW RI Diagnostics

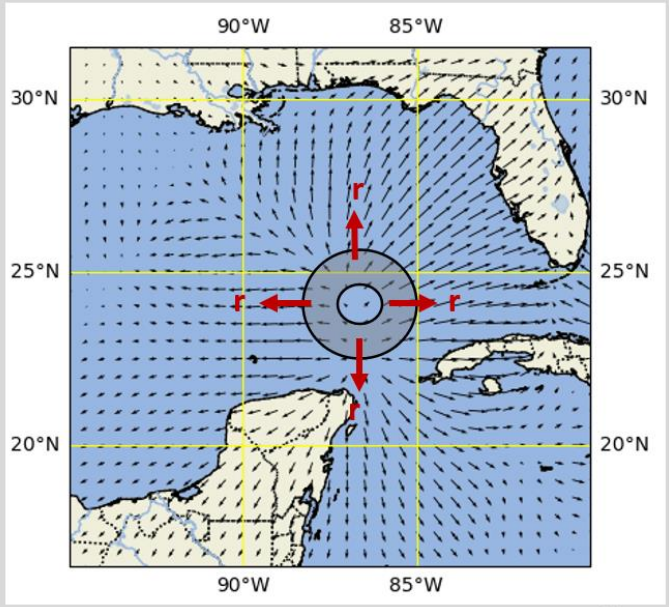
- Qualitative products for AWIPS2
  - Imagery, DMW displays
  - Divergent wind animations
- Quantitative products
  - Symmetric outflow parameter (SO)
  - Environmental flow blocking parameter (E)



AWIPS display of DMVs for Hurricane Laura

$SO = \mathbf{r} \circ \mathbf{V}_\chi$

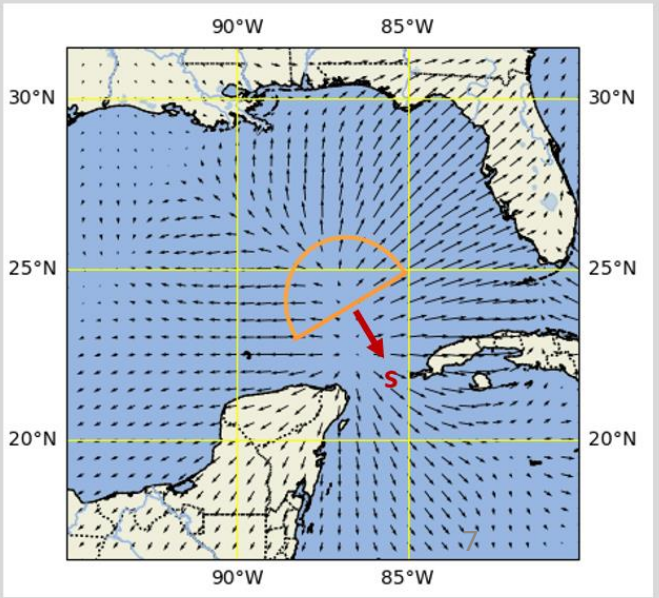
r = unit **vector** in radial direction



$E = \mathbf{s} \circ \mathbf{V}_\chi$

s = **S**/|**S**| = unit **vector**

S = shear **vector**



GOES GLM: Lightning and TC intensity change

Project Objective

- Examine GLM spatial structure and temporal variability to supplement TC intensity forecasts
- Develop a real-time tool for TC intensity change that uses GLM lightning

Methods

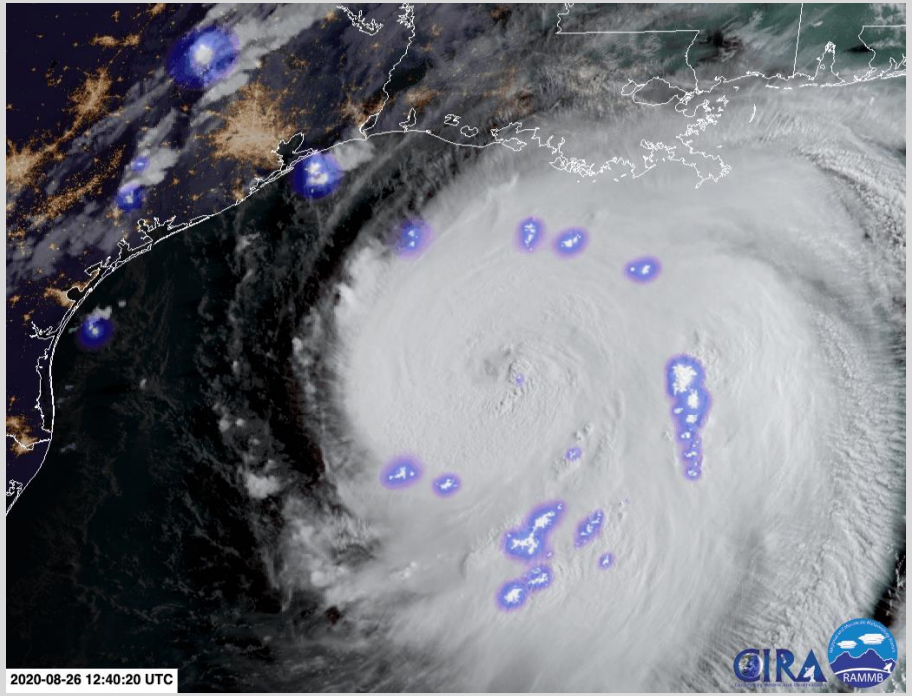
- Discriminant analysis (similar to SHIPS-RII)
- Machine learning

Status

- Real time demo 2022 or 2023

Core Team

Stephanie Stevenson (NOAA/NHC), Chris Slocum (NESDIS/STAR)



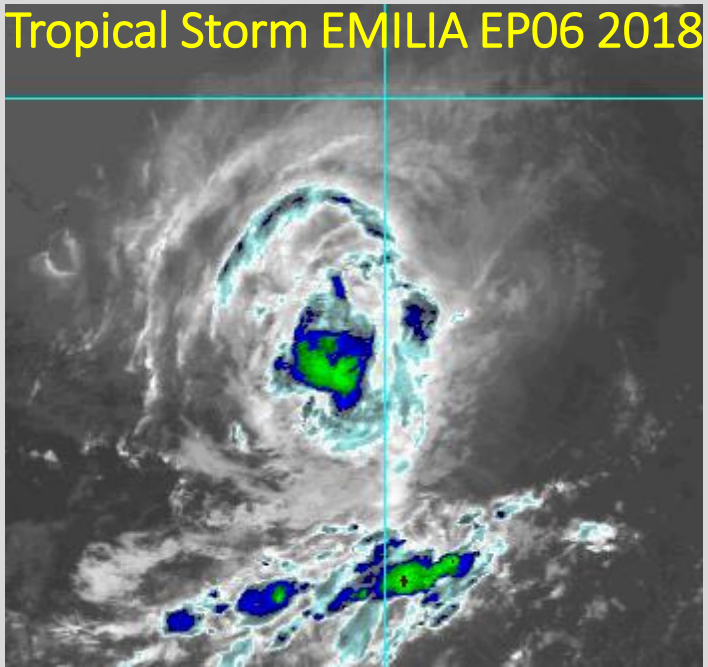
Major Hurricane Laura (2020)

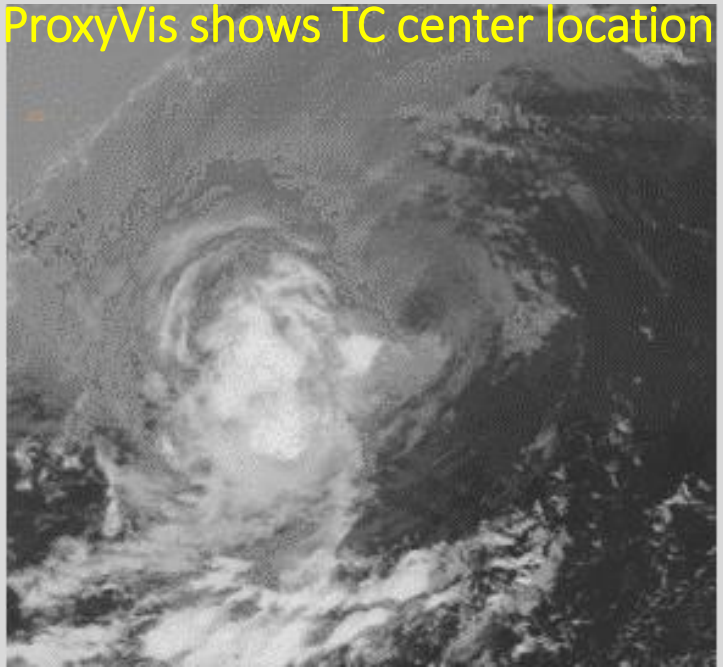
ProxyVis Imagery

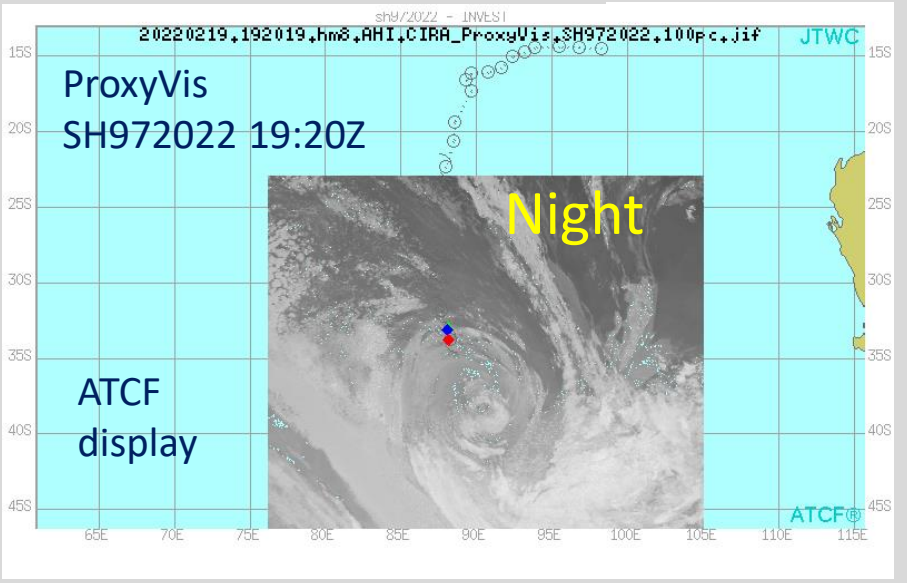
- ProxyVis Imagery combines into a single visible-like full disk imagery
  - DayTime: Normalized Vis channel
  - NightTime: Several IR channels combined to create visible-like imagery
- Most useful: tracking low-level clouds at night, locating LLCC for weak and sheared TCs
- Operational use:
  - NHC: part of standard operational suite; OPC/WPC: available in NAWIPS
  - Implemented in ATCF (operational by May 2022 for GOES-16,-17, Himawari)
  - Working on providing full-disk imagery in real-time to JTWC
- Working on improving for specific conditions (land/ocean, low/high lats, ET)

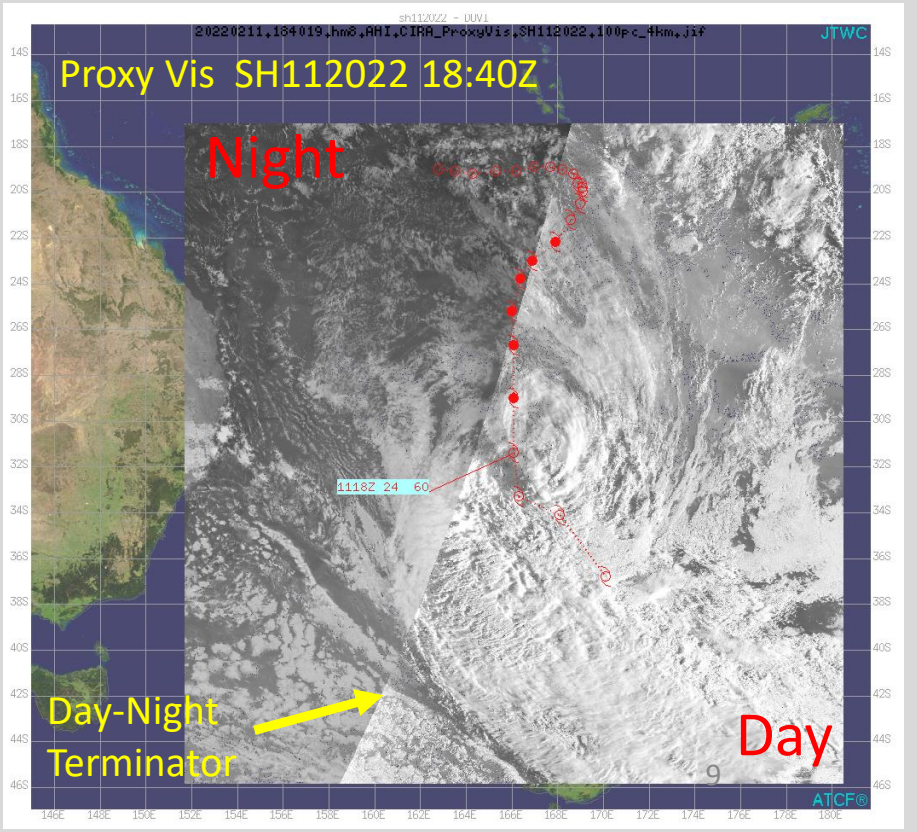
Project lead: Galina Chirokova (CIRA)

Implementation in ATCF via GeoIPS: Melinda Surratt, Buck Sampson (NRL)









Global ProxyVis Imagery

ProxyVis in real-time on SLIDER https://rammb-slider.cira.colostate.edu/

- GOES-16
- GOES_17
- Himawari

Summer 2022:

- Meteosat-8(Indian Ocean)
- Meteosat-11 (East Atlantic)

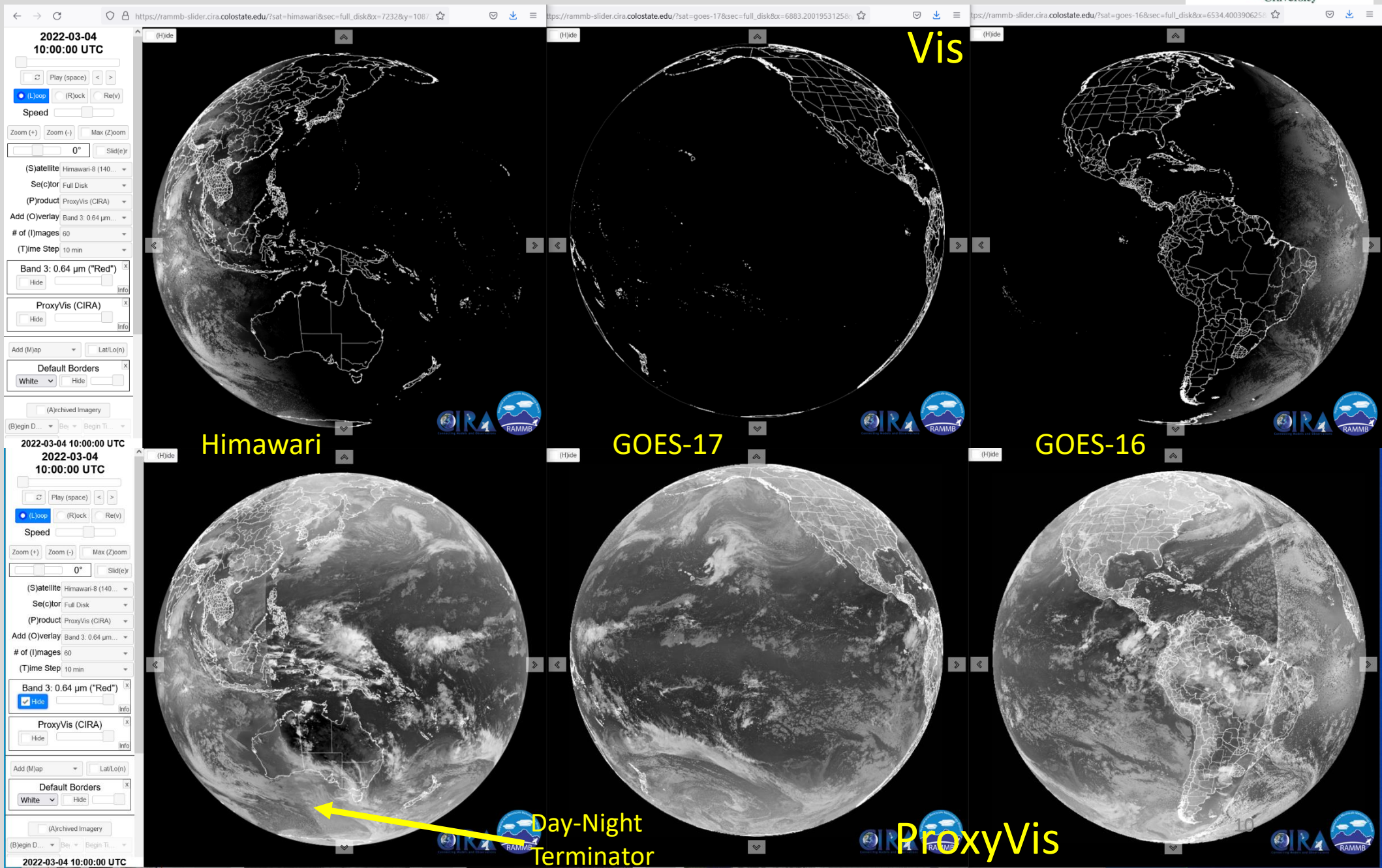
TOWER-S Cloud generates AWIPS2 ProxyVis for

- GOES-16
- GOES-17

And working on providing in real-time to

- Alaska Region
- Pacific Region (CPHC)
- GOES-17 – adding a version that works during heat loop pipe issues

POC: G. Chirokova



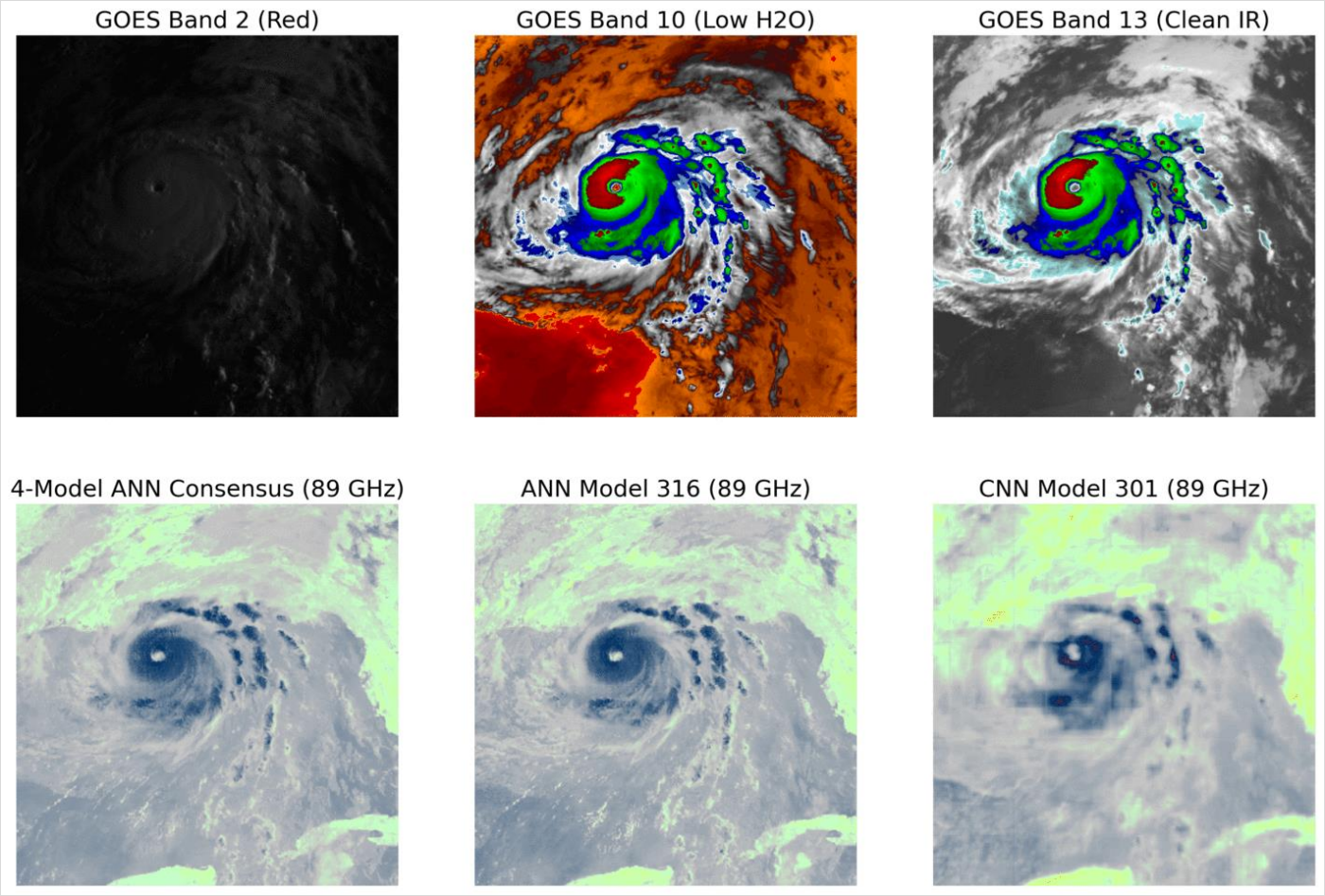
GeoColor Imagery

- Daytime visible color image
  - Estimates green from Vis, SW/IR channels
- 11-3.9 µm IR channel difference at night
- Static city lights image background at night
- Future plans
  - Add ProxyVis as a layer at nighttime
  - Add SST layer
  - Update ISatSS version for new capabilities
- Project Team:
  - Steve Miller, Dakota Smith, NRL

GeoColor loop for Hurricane Sally (2020)

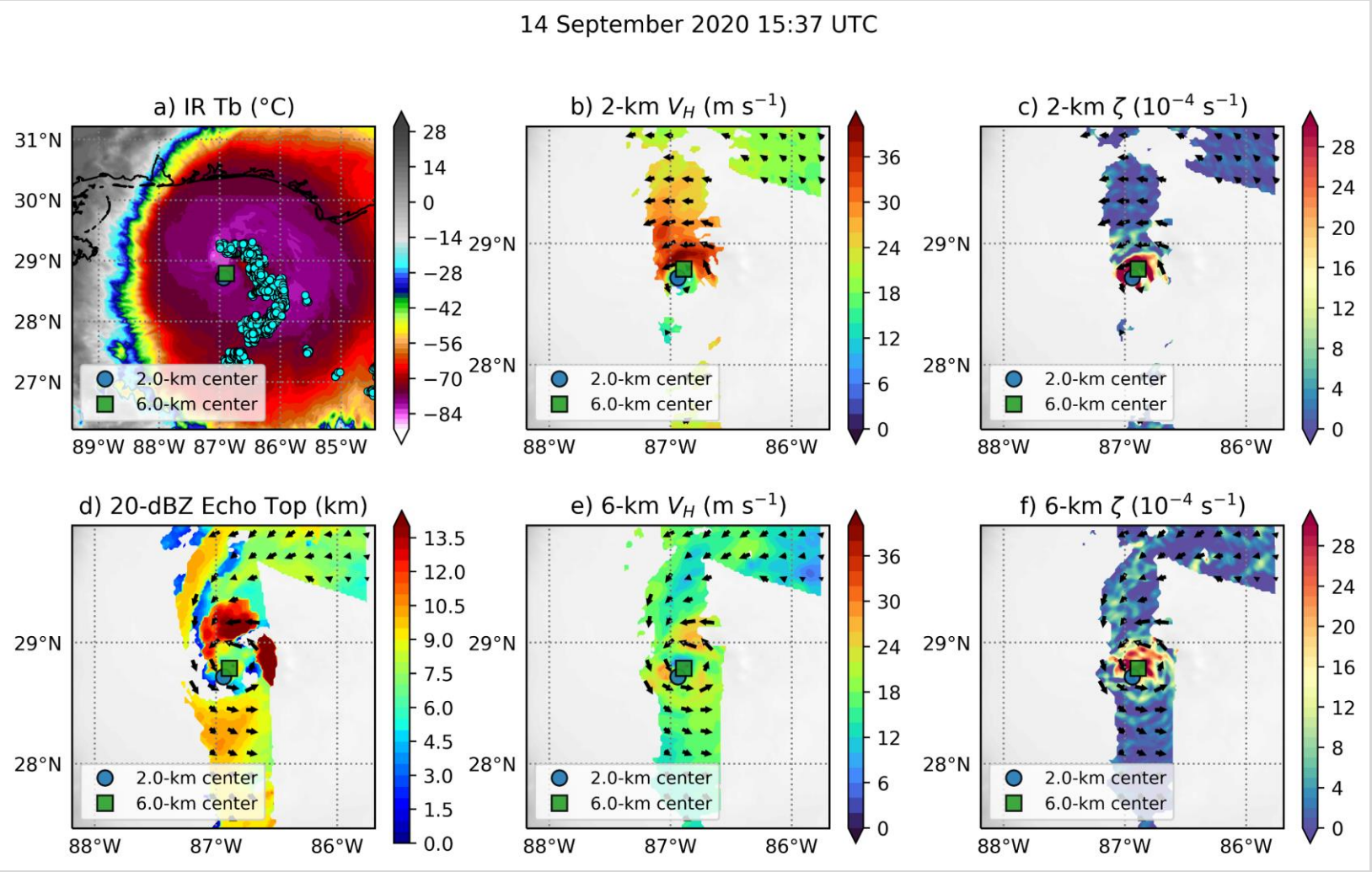
Using Machine Learning to Simulate 89-GHz Imagery from Geostationary Satellites

Hurricane Ida (2021), Trial Predictions



- Uses GOES-R series ABI as input
  - Train in microwave imagery
- Fills spatial and temporal gaps in coverage from LEO
- Experts can study evolution of tropical cyclone convective structure
- Working to find the “best” configuration that provides useful always-available information
- POCs: Chris Slocum, Stephanie Stevenson, Kathy Haynes

Combined GOES/Aircraft TDR Products



- AWIPS2 displays of GOES and P-3 TDR wind analysis
- Highlights active convection, wind structure, vortex tilt
- Qualitative product for situational awareness
- Quantitative product
  - Vertical tilt
- POCs: Michael Fischer HRD, Stephanie Stevenson NHC

Candidate JPSS Satellite Proving Ground Products

- Hurricane Intensity and Structure Algorithm (HISA)
- Moisture In-flux Storm Tool (MIST)
- AI-based surface wind field estimation tool
- TROPICS products

Hurricane Intensity and Structure Algorithm (HISA)

- Use temperature and moisture retrievals from satellite microwave sounders: AMSU, ATMS, TROPICS

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NESDIS Experimental Microwave TC Intensity/Size Estimation

Tropical Cyclone  AL202020       TEDDY
Current    date/time:    0 0000 0000 UTC
ATCF file  date/time: 2020 0918 1800 UTC

ATMS swath date/time: 2020 0918 1712 UTC

Minimum Sea-Level Pressure:   949 hPa
Maximum Surface Winds:        107 kt

34 kt wind radii (NE,SE,SW,NW):  402 284 186 252  nmi
50 kt wind radii (NE,SE,SW,NW):  101  80  60  74  nmi
64 kt wind radii (NE,SE,SW,NW):   43  36  29  34  nmi

ATMS-retrieved max wind radius:    8 nmi

Storm center is  393 km from ATMS swath center
              0-300 km is optimal
            300-600 km is adequate
              >600 km is marginal

ATMS data is   -1 hr from time of ATCF input

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ATCF File Input:
AL202020 0918 1800 UTC

Storm lat,lon (t =   0 hr):  22.50  -56.50
Storm lat,lon (t = -12 hr):  21.10  -55.10
Storm lat,lon (t =  -1 hr):  22.41  -56.41 (ATMS swath time

Storm max winds (ATCF):  105 kt
Storm heading:           324 deg
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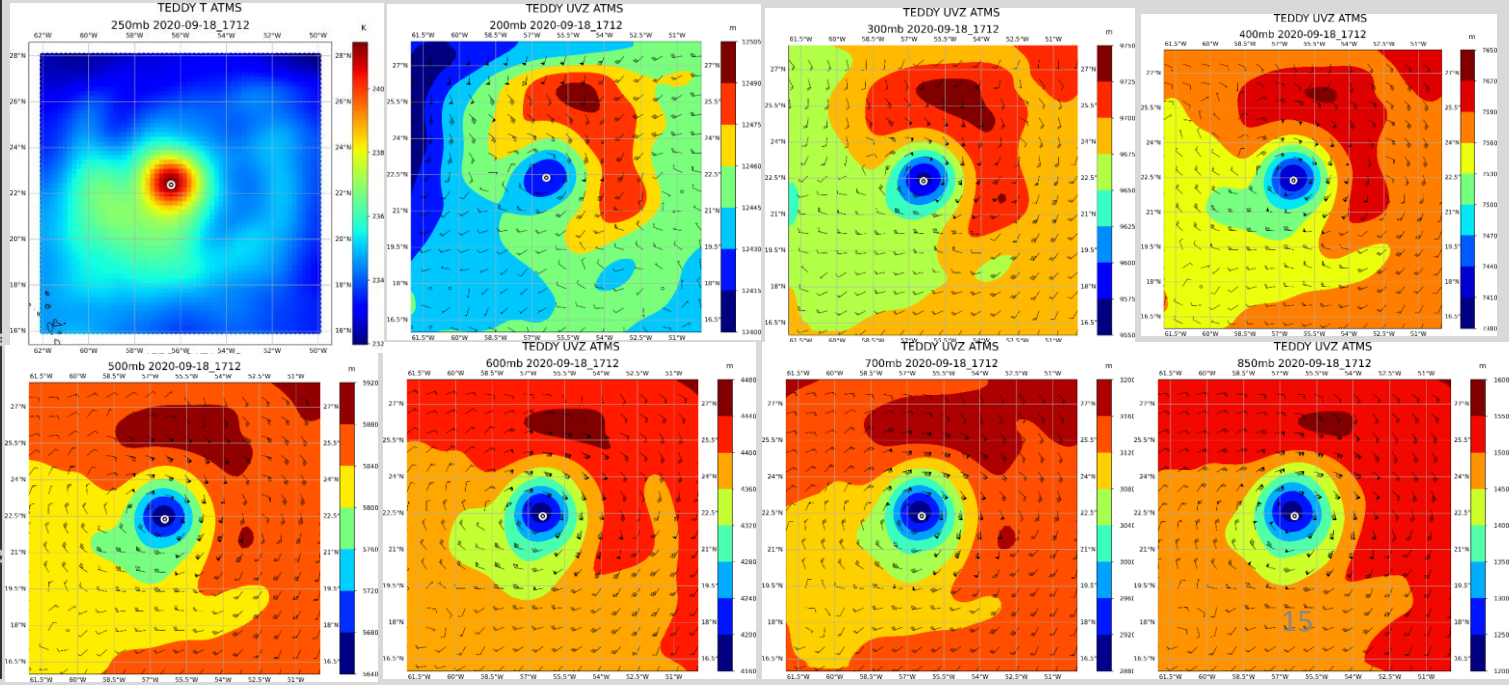
- Integrate hydrostatic equation to get pressure/geopotential height fields
- Gradient and nonlinear balance equations for 1-D and 2-D horizontal winds
- Statistical adjustments for bias corrections due to limited resolution, precipitation attenuation
- Output Vmax, MSLP, R34, R50, R64
  - used by SATCON, MTSWA

POCs: G. Chirokova, M. DeMaria (CIRA), J. Knaff (NESDIS/STAR/RAMMB)



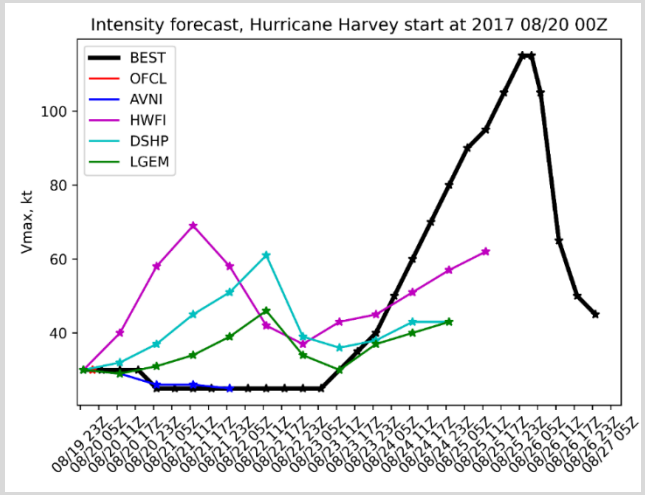
JPSS: Moisture In-Flux Storm Tool (MIST)

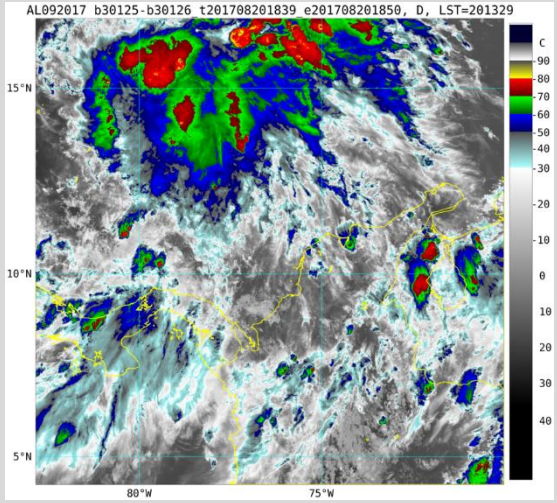
- Dry air intrusions adversely affect TCs
- Existing tools:
  - do not provide the exact location of dry air
  - do not allow to quantify dry air intrusions
- MIST provides quantitative information about dry-air intrusions

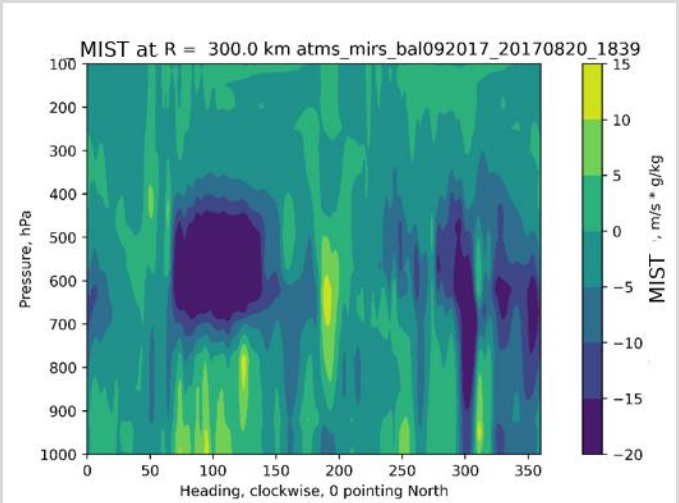
MIST
- satellite-derived moisture: SNPP, NOAA-20 ATMS-MiRS
- horizontal winds from GFS analyses
- MIST as a function of pressure and azimuth for given radius
- potential SHIPS and RII predictor, AWIPS2 display

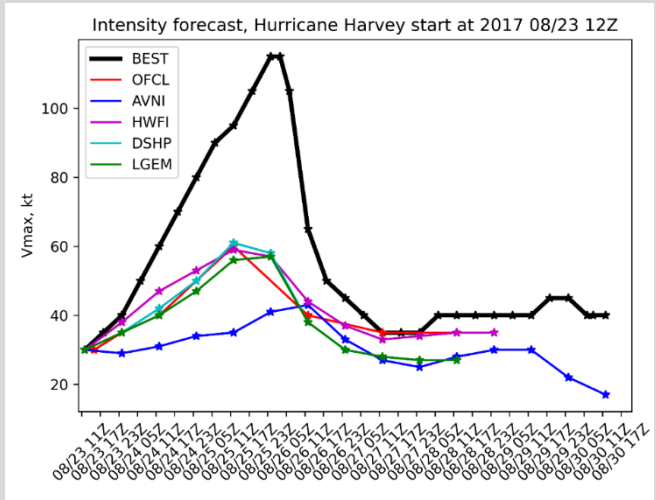
2017 Hurricane Harvey

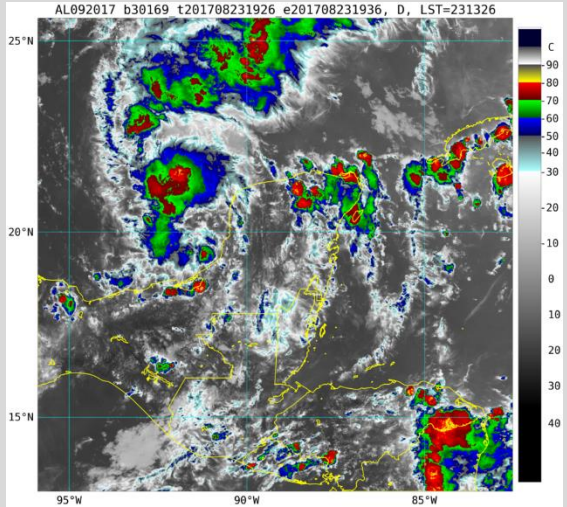
- On 23 August, in the beginning of the RI the storm is disorganized
- MIST indicates favorable environment for intensification
- MIST:
  - Blue – drying
  - Yellow - moistening

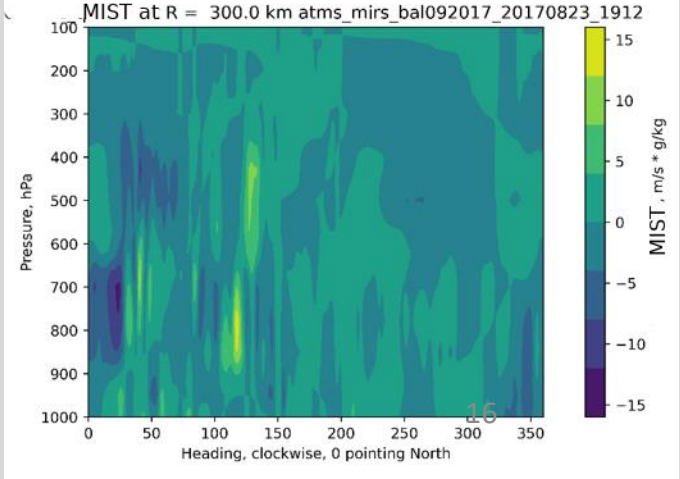










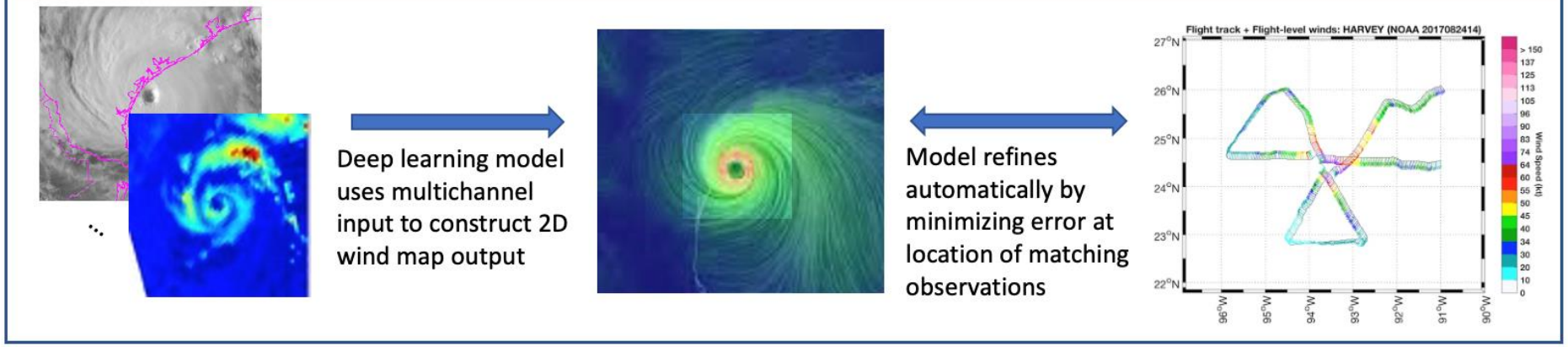


POCs: G. Chirokova, M. DeMaria (CIRA)

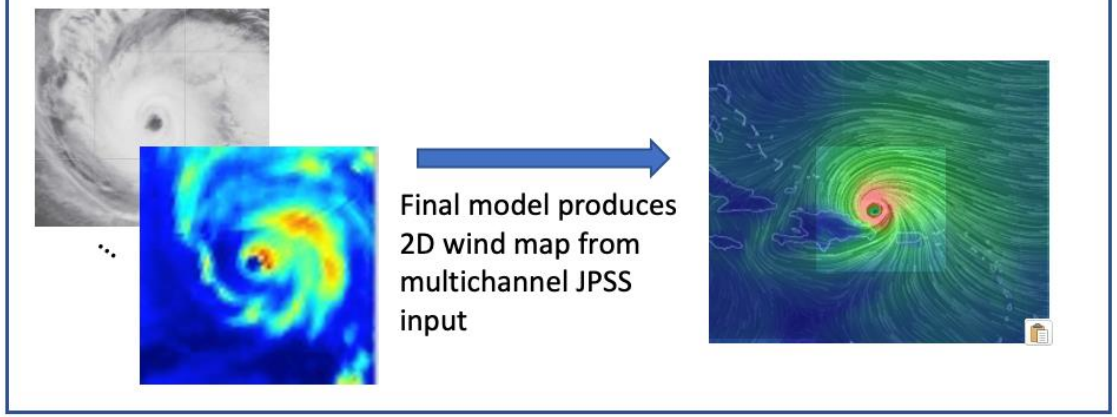
Direct integration of JPSS observations into tropical cyclone surface wind structure retrievals using deep learning

UW-CIMSS, PI: Anthony Wimmers

Training process (using hundreds of cases)



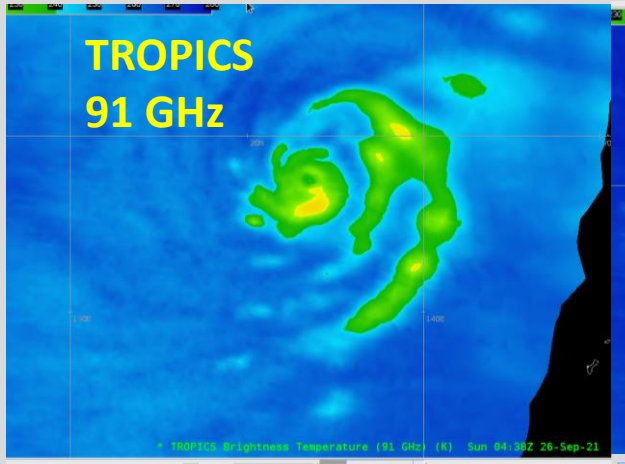
Operations (real-time or analysis)

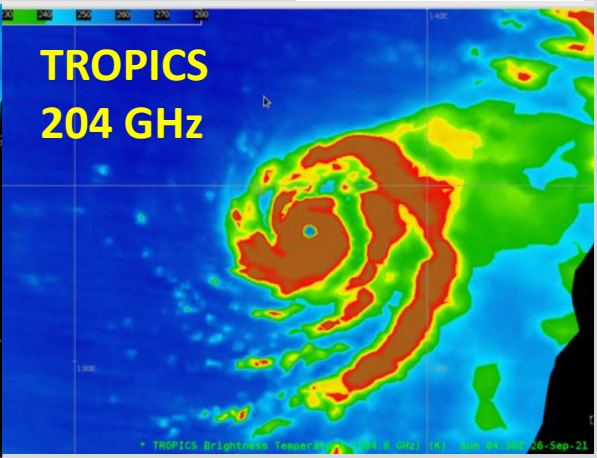


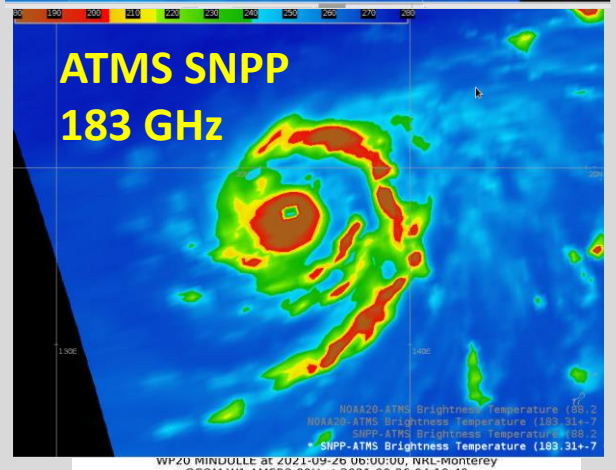
- Prior empirical approaches quantify a TC as simply a single intensity value, which limits its possibilities for understanding interactions within the TC and with the environment.
- A deep learning model allows us to infer wind *structure* from satellite and estimate the TC's rich 2D surface state.

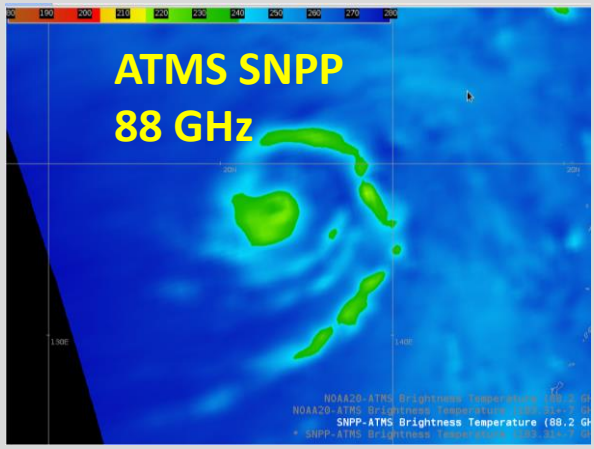
TROPICS Mission

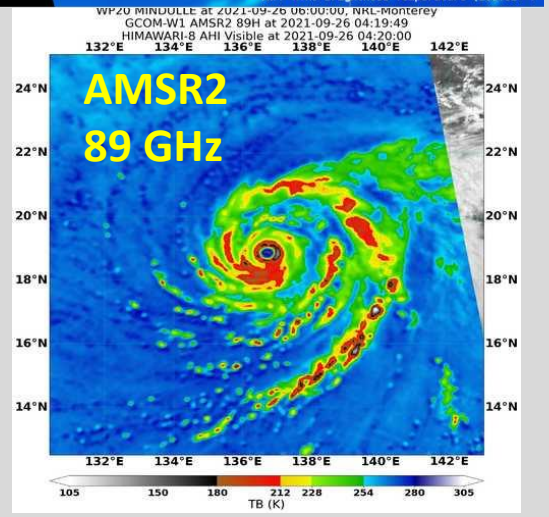
- Constellation of 6 CubeSats (30^{o} inclination orbit, planned Launch in 2022)
  - Pathfinder (sun-synchronous orbit), launched in 2021, real-time data available now
- 12 channel microwave sounder
  - 7 channels near 118.75 GHz Oxygen band for temperature
  - 3 channels near 183 GHz water vapor band for moisture
  - 91 GHz channel for precipitation structure
  - 204 GHz for water/ice microphysics
- Higher temporal and spatial resolution compared to ATMS
- Temperature and moisture profiles are created using Microwave Integrated Retrial System (MiRS). MiRS is operational for AMSU and ATMS allowing for direct comparison
- POCs: G. Chirokova, M. DeMaria (CIRA), P. Duran (SPoRT), D. Herndon (CIMSS)

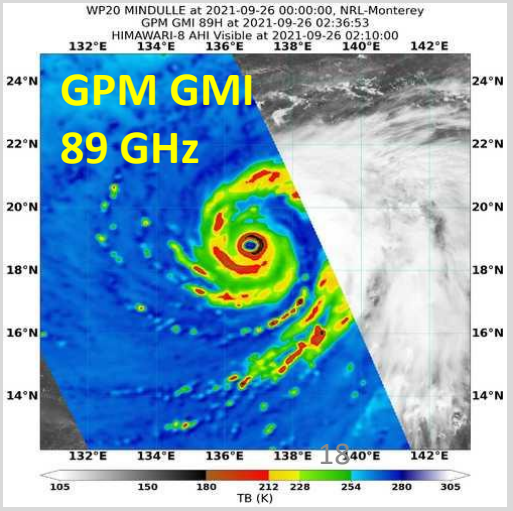












TROPICS Pathfinder Typhoon Mindulle overpass 09/26/2021 05:21 UTC vs other available MW imagery

TROPICS demonstrations

AWIPS2: available now

- Single channel imagery display in AWIPS2-ready format
- Possible real-time demos for NHC and JTWC in 2022
- Pathfinder mission data available now in real-time

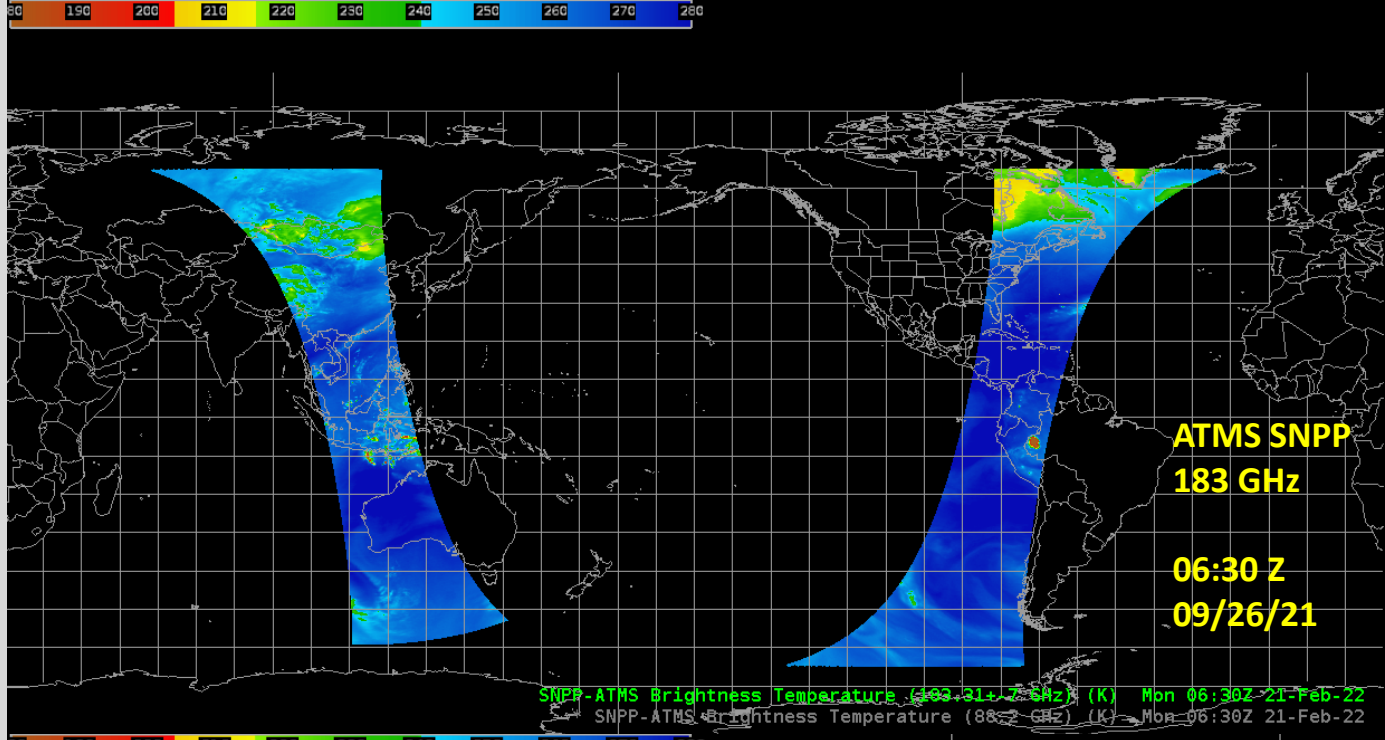
Future plans:

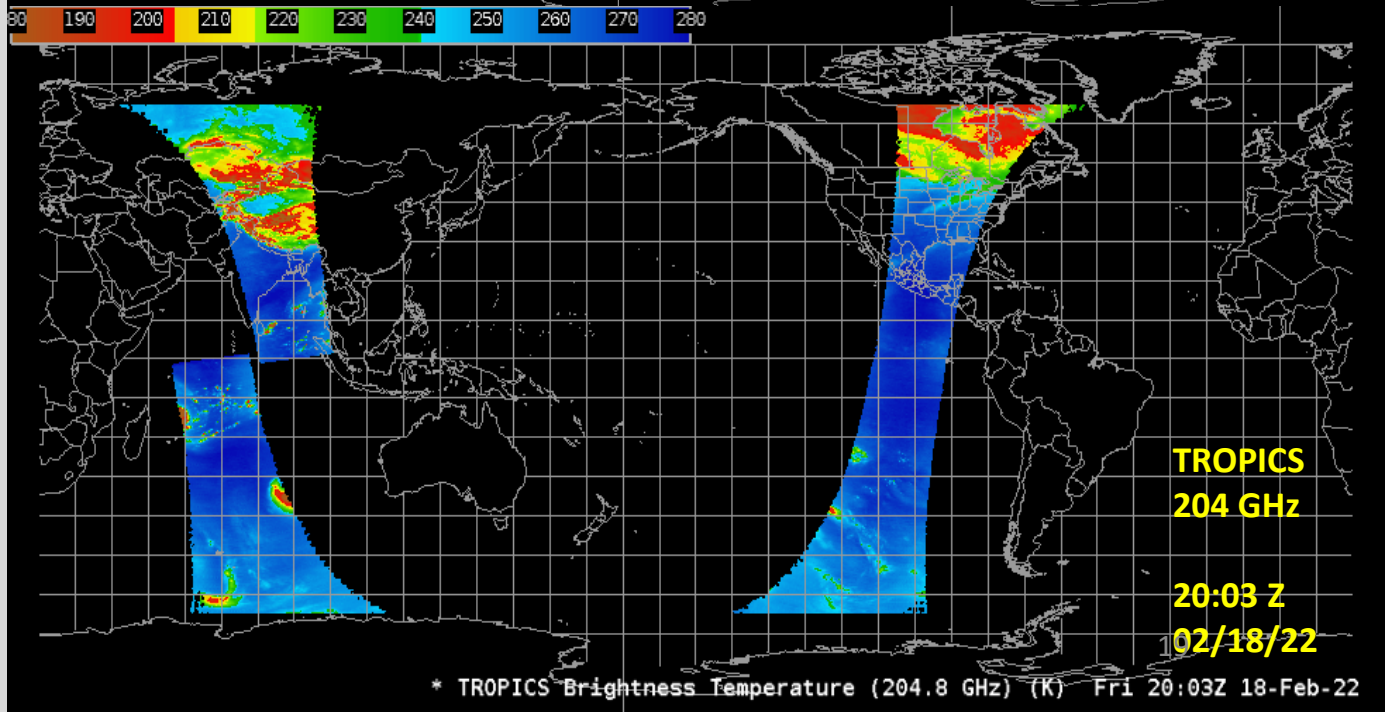
- Looking at limb correction
- Develop additional displays, including cross-sections with MiRS retrievals

Algorithms:

- CIRA and CIMSS TC intensity/wind structure estimation algorithms
  - Adapt from AMSU/ATMS versions

- POCs: G. Chirokova, M. DeMaria (CIRA), P. Duran (SPoRT), D. Herndon (CIMSS)





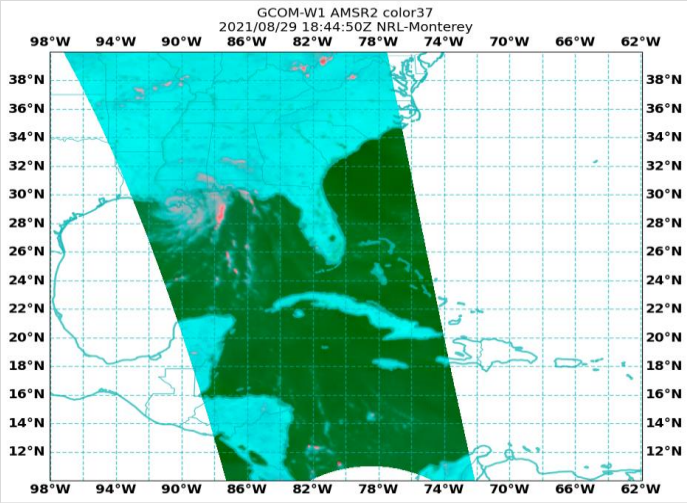
New Infrastructure for Product Demonstrations

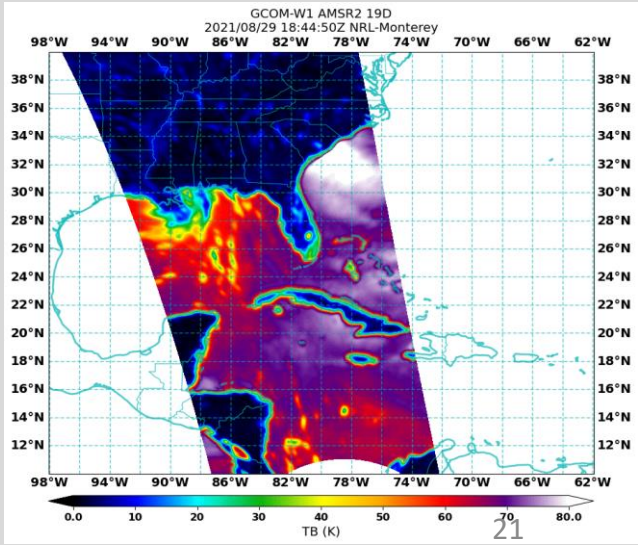
- Hurricane and Oceans Testbed (HOT)
- Real-time microwave data processing system for NHC (GeoIPS)
- AWIPS in the Cloud

Remodeled NHC Library for the HOT

Navy GeoIPS® Microwave Data Processing System

- Being developed with partial support from JPSS-PG/RR TC initiative
- **Will provide an operational system at NHC for microwave satellite data processing**
- Running stably on NHC VM since 2020
  - Updated to latest open source release (2.1.3)
  - https://github.com/USNavalResearchLaboratory/geoips2
  - Processing NOAA PDA and JPSS Direct Broadcast (DB) data for latency comparison purposes
- DB data become available substantially sooner than NOAA PDA data (~20 min)
- Sample DB AMSR2 outputs for Hurricane Ida prior to landfall in animations
  - 19, 37, 89 GHz H-pol & (H - V)pol difference
  - Low-level, Hydrometeor, color89 & color37 RGBS

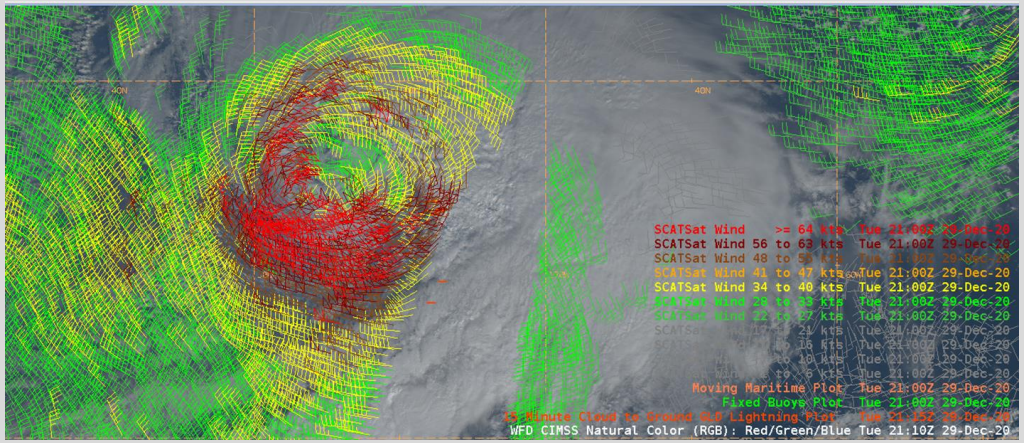


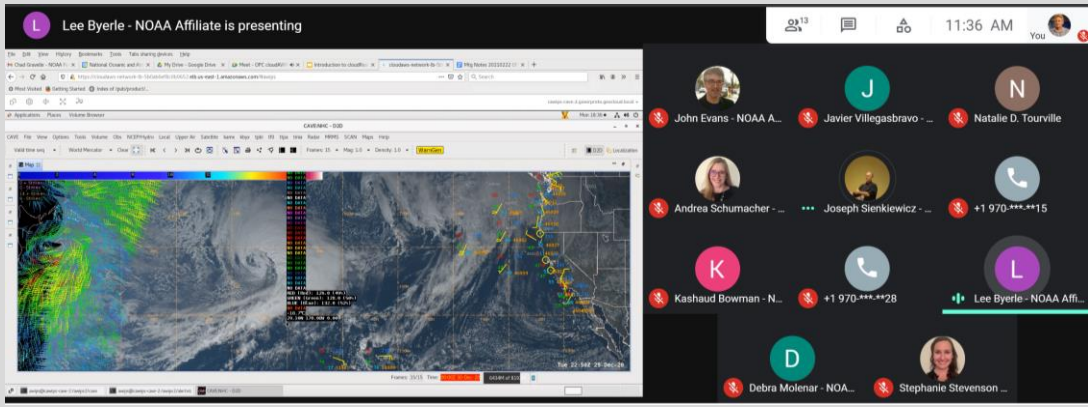


AWIPS in the Cloud for Enhanced Forecaster-Developer Interactions

- NESDIS TOWR-S Developing Cloud AWIPS
- Viewed/ controlled jointly via internet by forecasters and development
- 30-day data archive
- Longer-term archive on request
- Can include NCEP or WFO domains
- cloudReach sessions with small groups of developers and forecasters
- Similar capabilities being developed at GRL for NHC
- POCs:

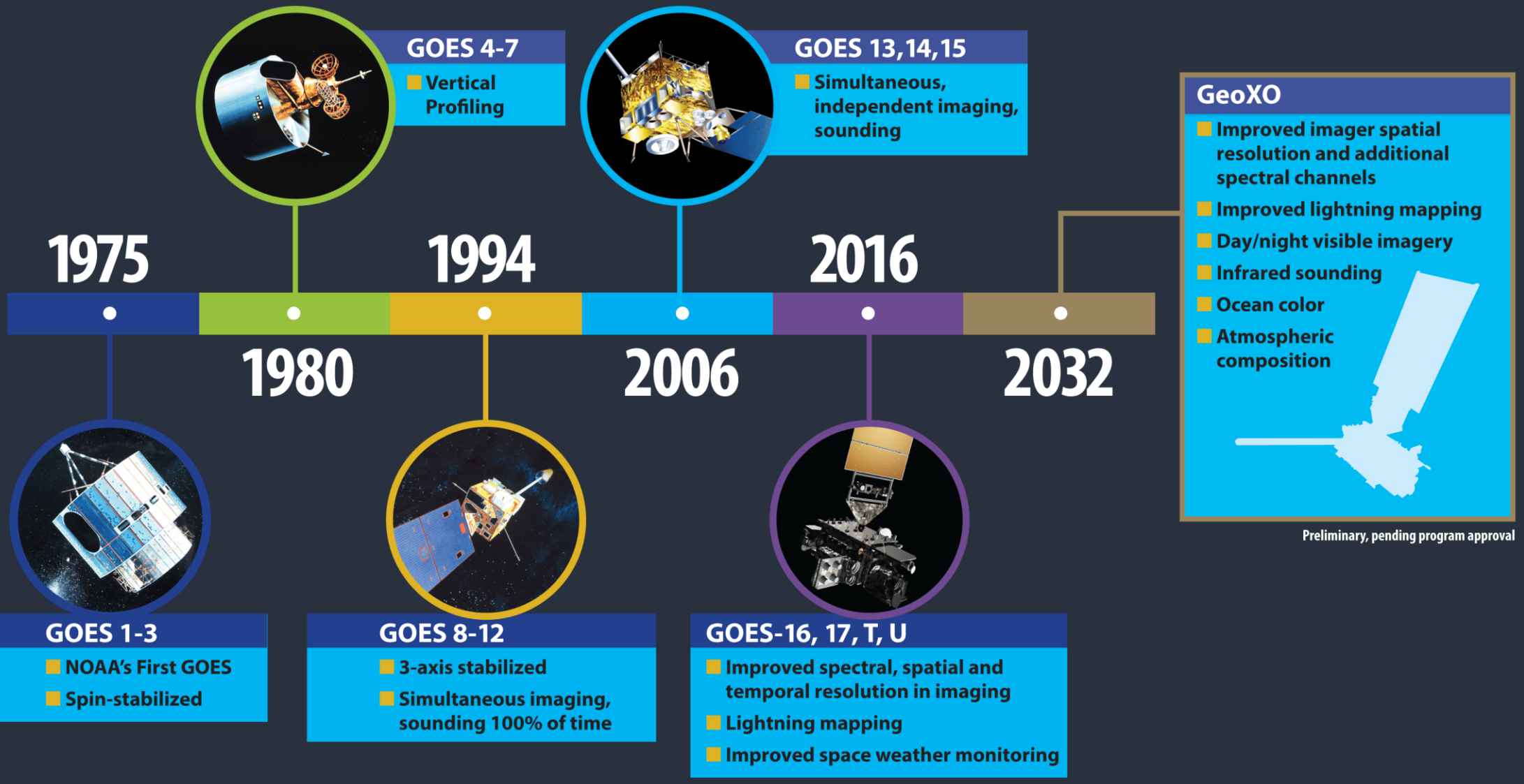
Lee.byerle@noaa.gov Kashad.Brown@noaa.gov





AWIPS Cloud Screen Captures from Cloud Reach Session with TOWR-S, OPC, NHC

History of Geostationary Operational Environmental Satellites




JHT


JTTI


HFIP


TSB


Satellite Proving Ground


NHC
Operations

Summary

- The Satellite Proving Ground is providing framework for demonstrations of new TC analysis/forecasting products
  - Complements the JHT and HOT
- Several products ready for demonstrations in 2022 or 2023
- DMW RI diagnostics
- Lightning-based RII
- Improved multi-spectral imagery products
  - GeoColor
  - ProxyVis
  - Simulated 89 GHz microwave imagery
- JPSS and TROPICS products
  - HISA and MIST from JPSS and TROPCIS
  - AI-based 2-D surface winds, TROPICS imagery displays in AWIPS
- GeoIPS and AWIPS in the Cloud will enhance forecaster-developer interactions
- Planning already underway for GeoXO (2032)